

THE COMBINED STRENGTH OF THERMODYNAMICS AND COMPARATIVE PLANETOLOGY: APPLICATION OF ACTIVITY MODELS TO CORE FORMATION IN TERRESTRIAL BODIES.

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Introduction: Recent models for accretion of terrestrial bodies involve metal-silicate equilibrium as the metallic core formed during growth [1-3]. Most elements considered are either refractory or well studied elements for which effects of pressure, temperature, oxygen fugacity, and metallic liquid composition are well known. There are a large number of elements that are both siderophile and volatile, whose fate in such models is unknown, largely due to a lack of data at comparable conditions and compositions (FeNi core with light elements such as S, C, Si, and O). We have focused on Ge, In, As, Sb and determined the effect of Si and C on metal-silicate partitioning, and developed a thermodynamic model that allows application of these new data to a wide range of planetary bodies.

New experiments: We have previously carried out experiments with FeSi metallic liquid at C-saturated conditions at 1600 and 1800 °C [4]. In a new series of experiments we investigate the effect of Si in carbon-free systems at 1600 °C for comparison. Experiments were carried out at 1 GPa in MgO capsules using the same basaltic starting composition as in previous studies. The MgO capsule reacts with the silicate melt to form more MgO-rich liquids that have 22-26 wt% MgO. Experimental metals and silicates were analyzed using a combination of electron microprobe analysis and laser ablation ICP-MS.

Results: The new results can be interpreted by considering Ge as an example, in the simple exchange equilibrium $\text{Fe} + \text{GeO} = \text{FeO} + \text{Ge}$, where the equilibrium constant K_d can be examined as a function of Si content of the metal. The slope of $\ln K_d$ vs. $(1 - X_{\text{Si}})$ for this new series allows derivation of the epsilon interaction parameter for each of these four elements and Si (both C-saturated and C-free). All four elements have positive epsilon values, indicating that Si causes a decrease in the partition coefficients; values are 6.6, 6.5, 27.8 and 25.2 for In, Ge, As, and Sb, respectively, at 1 GPa and 1600 °C. As an example of how large the effect of Si can be, these epsilon values correspond to activity coefficients (γ) for As of 0.01 when $X_{\text{Si}} = 0$, and up to $\gamma = 23$ when $X_{\text{Si}} = 0.2$. Combining these new results with previous determinations [5,6] of epsilon parameters for S and C for these elements allows us calculate activity of Ge, In, As, and Sb in Fe-Ni-Si-S-C-O metallic liquids. We apply this new model to several terrestrial bodies such as Earth (Si-rich core), Mars (S-rich core), Moon (S-, C-, and Si-poor core), and Vesta, and examine the resulting core and mantle concentrations of these elements. Mantle concentrations of these four elements are well explained for Earth and Mars in models that call for mid-mantle equilibration between Si-bearing and S-bearing FeNi cores, respectively. Modelling results for the Moon and Vesta will also be presented.

References: [1] Richter, K. 2011. *EPSL* 304, 158-167. [2] Siebert, J. et al. 2013. *Science* 339, 1194-1197. [3] Wade, J. and Wood, B.J. 2005. *EPSL* 236, 78-95. [4] Nickodem, K. et al. 2012. 43rd Lunar and Planetary Science Conference. Abstract # 2295. [5] Ma, Z. et al. 2001. *Metallurg. Mat. Trans. B* 32, 87-103. [6] Wood, B.J. et al. 2014. *GCA* 145, 248-267.